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HYDROLOGICAL ANALYSIS AND COMPUTATIONS: CHAPTER XVII, SECTION 70, "SERVICING THE RED ARMY"

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[Figures referred to are appended.]

In training for any military operation, each officer should study the physicogeographical conditions under which the operation is to take place. Knowledge of hydrology as part of the entire physicogeographical complex is compulsory for the officer, especially since different hydrological conditions have completely different and sometimes directly opposite meanings for the same military operation at different times of the year and in different years; for example, a swamp may be passable in the summer and impassable in the spring or fall. The hydrological background is particularly important in spring and fall, when abrupt hydrometeorological changes radically alter the conditions of military operations. River floods and bad roads of spring and autumn limit mechanized units and complicate front and army-wide communications, while freezing and debacle of rivers, lakes, and swamps introduce substantial corrections into the tactical evaluation of water barriers. A plan of military operations cannot be developed without concrete knowledge of and consideration for the hydrology of the territory, and the operation itself cannot be conducted without hydrological security.

The group of problems with which the military hydrologist should be concerned is not yet completely definite, and the tasks of the military hydrologist are very diverse. The role of the hydrologist becomes particularly important in the spring and fall periods. In the period preceding the spring bad roads and the spring high water, the hydrologist must accomplish the following preparatory work:

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1. Organize observations of the water-metering network.

2. Draw up flood diagrams during spring high-water period.

3. Compile a hydrological description of the territory occupied by the troops and of regions on which data is lacking in the handbook, and organize reconnaissance studies.

4. Organize snow-measuring and ice-measuring studies.

5. Forecast thaw time, the length of the spring period of bad roads, the time of river debacle, the height of spring high water, etc.

In summer, the command needs information on floods and river levels, road surveys, the passability of the territory in general and of swamps in particular, etc.

Forecasting of river freezing is most important in autumn. In winter, information must be produced on the passibility of ice and snow cover.

The data obtained from water-metering posts not only is used for information but also helps to prevent dangerous effects on local portages, main highways, and hydrotechnical constructions from various hydrological phenomena.

Reconnaissance of water barriers becomes very important in military operations and is often carried out together with engineering surveys to clarify the hydrographic information available on water barriers.

Diagrams of flood areas are drawn up for catastrophic years and for the coming years. This work is quite difficult, particularly for regions of small rivers, about which there is usually no information. The diagrams are drawn up for the coming year from forecasts and for catastrophic years. The boundaries are laid out on a map from the available data on hydrological conditions and later made more accurate from reconnaissance data. The flood diagram is a valuable document and is used for the regrouping of military positions, disposal of troops, and planning of work at the rear.

Troop movements occur from time to time, and thus new requirements for clarification of various hydrological reports are continuously submitted by the command. We have previously discussed [in other parts of the book] the influence of snow cover on troop movements, the connection of wetness of ground with the passability of territory, the passability of a territory as related to snow depth, intensification of water barriers by constructing water obstacles, the passability of ice covers, and an approximate method for the construction of curves for the volume of a reservoir. We now discuss several other problems of the military hydrologist.

<u>Production of Hydrological Observations and Studies</u>

In the organization of observations in an area where troops are located, attention is focused on the subject of levels. Two types of water-metering posts are established, i.e., river and swamp.

Rack posts (and not pile posts, as are used at the rear) are most commonly used. White paint should not be used for racks since this color is "decamouflaging"; when these racks are used, the percentage of water-metering observers injured by the enemy increases considerably.

At river and lake water-meterming posts, observations are made on water level, air and water temperatures, and ice phenomena. At swamp posts, observations are made on water levels, snow cover, depth of freezing, and passability of swamps.

Hydrological reconnaissance covers rivers, lakes, and swamps and consists of depth soundings, measurements of flow speeds, river discharges, observations on snow cover, and ice surveying.

The scope of the required studies, methods of setting up posts, production of reconnaissance and surveying data, and instruments and the required documentation are discussed in Instructions on Hydrometeorological Reconnaissance of Rivers, Lakes, and Swamps (Nastavleniye po gidrologicheskomy rekognostsirovaniyu rek, ozer, i bolot), edited by Ya. Ye. Dzhogan, Gidrometeoizdat, 1942, and compiled by the Main Administration of the Hydrometeorological Service (GUGMS).

Samples of Hydrometeorological Service

The military hydrologist must be able to compile the following for the command hydrometeorological surveys; hydrometeorological summaries, reports of dangerous hydrometeorological phenomena, etc., from weather and hydrological forecasts, and from observational data of water-metering post surveys. Samples of these documents are given below.

1. Text of a Hydrometeorological Summary, Entered in the Diary (see Table 1, column 8)

Cloudiness along the entire front is 5-7 with a short-period increase to 10 in the afternoon; cloud heights from 600 to 2,000 meters. Cloudiness changing to clear at night. A slight fog with visibility up to 2 kilometers in the morning in the lowlands on the left and central sections of the front. West wind; velocity at night is from calm to 5 meters per second and during the day, from 4 to 6 meters per second with gusts up to 10 meters per second. Temperature at night is 14-16°; during the day, 23-25°.

The level continues to drop on all rivers of the front, from 3 to 10 centimeters per day on rivers of the left and right flanks and from 20-60 centimeters per day in the central sector.

Sunrise is 0409 hours; sunset, 2119 hours (Moscow time). Dispatched 7 July 1942 at 1800 hours.

Table 1. Diary of the Hydrometeorological Background for Region --- of the Front -

Date, Month	Text of a Short-Range Forecast for a Given Date, Obtained by the Division. Time and from Whom Obtained	Text of a Short-Range Forecast Transmitted to Staff Subdivisions or Army Units. To Whom and When (time and how transmitted)	Rating of Justification of Individual Forecast	Storm Warnings. To Whom, When (time), and Basis for Warning	Rating of Justification of Warning	Detailed Hydrometeorological Background for the Front Region for the Given Date, with an Indication of the Time (from -- hr to -- hr)	Text of Hydrometeorological Summary, Indicating Time of Delivery	Notes

2. Sample of a Brief Hydrological Summary

The following is a sample form of a brief hydrological summary:

Hydrological Summary for 16 April 1942

The ice cover on river K at point X, on river B at point Y, and on river C at point M is 60-70 centimeters flooded. In places the ice is upheaved, water holes are noted, the movement of cracked ice from explosions on the ice is observed. Ice crossings are impossible.

Flooding of 40-60 centimeter's on swamps in the region of points D, E, and A. Swamps and low spots are impassable.

Automobile movement is impossible on roads in the regions of points M and K. Intensive thawing is observed. The snow has thawed on high spots in the field. A water rise of 50-60 centimeters was noted in the past 24 hours on rivers K, B, and C.

Debacle is about to occur on rivers in the area of army operations.

3. Samples of Hydrological Surveys

a. Sample Forms for Reporting the State of Rivers

State of Rivers, 16 April

River D: Debacle has begun; level has risen 80-100 centimeters.

River Y: Ice cover is broken; movement over the ice is impossible. Intensive thawing. A great deal of water is in hollows, gullies, and low spots along the banks. Average snow depth, 6-25 meters.

State of Rivers, 20 April

River D: Sparse drifting ice. Water level is 360-410 centimeters.

River Y: Sparse drifting ice. Water level is 430 centimeters. Passage through river in boats.

State of Rivers, 23 April

River D: Falling water level; drop of 62 centimeters in 24 hours.

River Y: Drop of 45 centimeters in 24 hours.

Final Forecast of the Drop of Spring Waters

End of the drop of spring waters on river C in the section from A to M is expected 7 - 9 June 1942.

b. Sample of a Warning Report

Military report No ---, Storm --- at 2200, 20 April 1942. During the night, the water level rose 36 centimeters at point K on river M, 132 centimeters at point X on river K, and 6 centimeters at point L on river Y. Icebreakers damaged by ice at points A and C of bridges. Work on blasting a passage through the ice continues.

C. Sample of Hydro Information

The river is ice-free. The snow cover has disappeared, remaining only in spots in valleys and forests. Roads are passable with great difficultly for auto transport. Temperature changed through zero on 29 March. Winter camouflaging was removed 25 March. There will be no ferry and pontoon crossings, only bridges will be used.

Military-Hydrological Description of an Area and Water Barriers

The hydrological description is drawn up on the basis of the available handbook material and reconnaissance data. The need for the latter is determined by the completeness of the available handbook data and the special assignments of the command; these conditions also determine the completeness of the description.

Ordinarily, the description should cover the water objects (rivers, lakes, swamps, etc.), and the adjacent area.

In drawing up the description, special attention should be given to problems connected with military operations, e.g., bridges, ferries, fords, etc. Other problems should be discussed only briefly. The entire description must be both brief and informative.

The description consists of two parts, the maps and the text description.

1. The Map

To supplement the text description, a number of elements must be laid out in colored pencil with conventional designations on the map of scale 1:50,000. This is done in the following order:

a. River Beds, Indicating:

(1) Impassable fords of sections in the period of average level (heavy blue pencil).

(2) Fords (light blue pencil of the section with the index "br" /Russian abbreviation for ford/), with the river bottom, the average width of the river, and depth of the ford.

(3) Flood boundaries in the average and high spring high water (the first in blue hatching, the second in a blue dotted line along the flood line).

(4) Sandbanks, showing depth.

(5) Average current speeds for fords and sandbanks.

b. Characteristics of Average-Level Shores

The following are indicated:

(1) Sharp and precipitous shores (special marks with a brown pencil).

(2) Elevation of river valleys in meters.

(3) Type of bottom.

(4) Swampiness and passibility of bottom land.

c. Characteristics of River Valleys

(1) Width.

 [redacted]

(2) Elevation of base shores in meters over the average level.

(3) Which shore commands (dominates) the valley.

(4) Characteristics of shore approaches, their slopes.

(5) Concealment of the valley by vegetation, type of woods, and thickness of tree trunks.

(6) Type of bottom.

d. Swampy Lands

(1) Swamp lines (blue hatching).

(2) Types of swamps.

(3) Passability of swamps.

e. Commanding Heights

Give contour (thick brown pencil) and height of commanding heights.

f. Artifical Constructions on Rivers

(1) Bridges, their location and characteristics. Type, length, width and length of thoroughfare. Height of bottom of the suspension structure over the average and highest levels. Information on the loadcarrying capacity of bridges. Roads.

(2) Ferries, their size, load-carrying capacity, and method of locomotion.

(3) Dams, their position, characteristics, type, length, width.

g. Planned Constructions

Planned constructions are indicated on the map by red dotted designations.

2. Descriptions

a. Rivers

Description of the rivers is given in sections. The sections are divided according to homogeneity of the morphometric elements. The sections must be small.

In the conclusion of the text description, a military-technical evaluation of the water barrier for each section must be given separately, with consideration of all elements indicated previously and the possibility of intensifying the barrier by hydrotechnical constructions.

In studying rivers for flooding and swamping, one must (1) carry out longitudinal leveling and transverse leveling along the axis of a dam and (2) measure the water discharge.

b. Lakes

Reconnaissance studies of a lake are conducted to: (1) determine its importance as water obstacle, especially if the lake together with other lakes, rivers, and swamps constitutes a water barrier and (2) determine whether the lake can be used as a seaplane base or as a landing area (in winter).

In the study of a lake, the following problems must be investigated: (1) the position and size of the lake (length, width, area, volume of water), (2) the lake shores, their height, curvature, soil, concealment, approaches to the lake, (3) depth and topography of the bottom, (4) soils of the bottom and their distribution, (5) information on water-level variations, time of debacle and freezing, characteristics of spring and fall ice movement, and ice thickness, and (6) utilization of the lake (navigation and floatage).

c. Swamps

Swamps are studied mainly to determine their seasonal passability for various types of troops. In the study of swamps, the following problems must be investigated:

(1) Position and size (length, width, area, swamp line).

(2) Type (upland, lowland, transitional, swampy territory).

(3) Type of surface (hillocks, semiliquid soft spots between the hillocks, ridges), lakes, rivers, and brooks passing through the swamp.

(4) Vegetation (trees, bushes, shrubs, grass, and moss).

(5) Passability by seasons in dependence on the wetness of the swamps. State and passability of roads, causeways, and paths crossing the swamp.

Soundings are made to determine the thickness of the turf and the type of underlying ground.

The passability of swamps is determined by personal observations, by interrogation of local residents, and by measurements with a special pole of a given weight.

3. Hydrological Description of a Position Occupied by Troops

The following is a sample of a hydrological description of a position occupied by troops of the N Command:

a. Precipitation

Precipitation is maximum in July (about 85-100 millimeters for the month). In the rainiest years, precipitation exceeds 200 millimeters in July. The number of days with heavy rainfall (above 10-20 millimeters) increases up to mid-summer and then decreases. The greatest precipitation (for 24 hours) reaches 90-100 millimeters in the period from July through August. In June and August, there are about 1-2 days with showers, possibly 3 in July, while showers are not observed every year in September. In most cases, showers last 5-10 minutes, but there have been cases where they lasted 15 minutes, with 45 millimeters of rain fall.

b. Regime for V River

The average-level period, which is distinguished by low, relatively stable levels, occurs in the last days of April or the beginning of May and lasts 3-4 months. Low water is most frequently observed from August to October. There are usually considerable floods 3-4 times during the summer. The river rises rapidly, in some cases, 2-2.5 meters per day. It drops more slowly, the maximum being 50-80 centimeters per day. The level begins to rise after 1.5-2 days, and the rain floods last 2-7 days. During absolute low water, fords (in which the river abounds at this time) are revealed in many cases. The depths of fords during low water varies from 0.4 to 0.6 meter; the width is 25-30 meters;

the speed of flow is 0.6 meter per second. High vegetation grows in many places along the banks of the river bed. The soil of the bottom is mostly solid (sand with gravel) and will support heavy tanks.

c. Characteristics of the Barrier along River V (according to individual sections)

Section No 1 from M to V. Length --- Kilometers

The shore is alternately steep and slanting. On the left side, the steep part of the shore is 10 meters high northwest of point G. On the right side the steep part of the shore is 15-20 meters high southeast of A and northeast of B, and about 6 meters high east of B and 12 meters high south of B.

In the remaining places the shores are slanting and accessible to tanks. The left shore is predominant at K, and the right at B. Commanding heights on the left side: the height northwest of G along contour line 170, points 179.5 and 187.7; on the right side, north of M along contour line 185, point 188.8. The left shore is covered with forest from M to K; the right is open, with the exception of a grove southeast of A. From K to V the left shore is open, while the right is covered by a forest.

There are fords at V and K, with depths of 0.3-0.5 meter in shallow water. The approaches to the fords are covered at V on the left shore and at K on the right.

There is a dam at P with a head of 2.5 meters, at present half-destroyed.

The bottom is predominately clayey soil. The network of dirt roads is well developed.

d. Tributaries of River V.

There are tributaries on the left side of river V in the form of brooks. Brook P is the largest of them. They can serve as water barriers only in the spring at high water and during summer floods. The water level rises 1-2.5 meters. Rain floods last 1-2 days.

e. Swamps

The level is minimum in August-September.

The group of swamps south of P has a total area of about one square kilometer. The turf is no deeper than 30 centimeters. The swamps are of the upland type. The surface is covered with grass vegetation, and hillocks. The swamps are flooded with water in rainy periods in the spring, summer, and fall. The swamps are passable for cavalry in the dry period.

f. Swampy Land

The swampy land bends round an arc of the outskirts of a forest southwest of Y. This belt is 250-500 meters wide. The depth of the turf is less than 30 centimeters. The vegetation is grassy with deciduous shrub growth. Hillocks prevail. The swampiness is not great in the dry period, and cavalry can cross. A tractor can cross only with great difficulty.

g. Sample of Brief Characteristics of Boundary Along River N

Section No 1 from S to K. Length --- Kilometers

River N is fed from a lake and is over 1.5 meters deep, 14-40 meters wide.

The valley is 50-100 meters wide. The main shores are 3-6 meters high, sloping at point R and steep at point S.

There are favorable approaches to shores at T.

There are bridges at Kh and G.

Section No 2 from K to M. Length --- Kilometers

The river is passable everywhere by fording. Depth, 0.4-1.0 meters. Width, 8-20 meters. Full of rapids in places.

The valley is 150-400 meters wide. The bottom land is swampy. The left shore is slightly sloping. The valley is thickly overgrown from S to U.

The base shores are 3-8 kilometers high. In many places the river borders on the right main shores. There is a forest along the shores.

There are convenient approaches to the shores between V and M.

There are bridges at L and Kh.

An earth dam with a wooden floodgate is located 100 meters below the mouth of tributary A. The head is 1.4 meters. The dam is 150 meters long.

Drawing up Flood Diagrams of Bottom-Land Sectors of Rivers

A flood plan is drawn up on the basis of:

1. A map of scale 1:50,000

2. Long-range hydrological forecasts obtained from the GUGMS (Main Administration of the Hydrometeorological Service).

3. Observational data of local administrations of the Hydrometeorological Service. Selected data from the administrations is attached to the explanatory notes.

If the maximum discharge of the flood or high water to be forecast is known for a number of river stations, the levels corresponding to these points can be determined from formulas of river hydraulics. The method of hydraulic moduli can also be used. More accurate results will be obtained if the level is determined from a curve of discharges versus levels, if such a curve exists.

The flood boundaries are laid out arbitrarily, especially for small rivers. Low accuracy results from the fact that the horizontals on the 1:50,000 map are shown every 10 meters while the maximum amplitude is 8-10 meters or even less on small rivers. The duration of the spring high water, which depends on the river length, should also be given here.

The debacle times of rivers must also be indicated. For example, it should be indicated that debacle is most probable at the beginning of the second 10 days of April.

The boundaries of the spring flood should be made more accurate by reconnaissance of the water barriers and interrogation of local residents when the flood plan is to be used to design portages or water barriers.

The problem of intensification of water barriers by construction of water obstacles was discussed previously /in another section of the book/.

Production of Hydrological Work in Connection with the Construction of Permanent Fortifications

Efficient disposition of fortifications requires consideration of the following:

1. Level of ground waters during construction and operation of the installations.

2. Variation of ground-water levels in connection with precipitation and seasons.

3. Direction and magnitude of surface flow.

4. Amount of shower flow, to design the sewage system of the fortified region.

5. Boundaries of water rise in adjacent streams and reservoirs during spring high water and floods.

6. Chemical composition of ground waters, to calculate and prevent deleterious effects on concrete.

7. Presence of caverns which might be used as fortifications.

Field Water Supply

Water supply of troops should be based on ground water, either by using existing wells or constructing new ones. Water supply from surface sources (rivers, streams, ponds, lakes) is permissible only when ground waters are not present or lie at great depth. Automotive equipment can be washed with water from surface sources. Norms for the water requirements for servicing and washing mobile equipment are as follows (in liters):

Type	For Servicing Cooling System	For Washing
GAZ automobile	12	150
ZIS automobile	26	400
ChTZ tractor	60	400
Light tank	22	250
Tank	100	500

Forcing Water Barriers

Crossing a river in combat is called forcing. It can be accomplished by fording, swimming, crossing ice, by floating devices, and also by bridges. Forcing is distinguished from an ordinary attack on an armed enemy by the fact that the attacker must first cross a river under organized defensive fire. This is very complex type of battle, demanding careful training and organization, since each delay in the crossing is accompanied by heavy casualties, while an interruption or halt in the crossing may lead to disruption of the entire operation.

The hydrologist should have a detailed map of the river for preliminary selection of the crossing site. These maps, however, are ordinarily available only for navigable rivers; therefore, a detailed plan of small rivers or their individual sections usually must be drawn up on the basis of reconnaissance and small-scale maps.

Aviation reconnaissance, map descriptions, and interrogation of local residents should be used to obtain the best possible selection of a site. In many cases, aerial photographic surveying of rivers and surrounding territory has given exhaustive information of the state of the river and its bottom land and valley. Surveying must initially establish whether fords are present and if so, their location and state. Indications of fords are roads or paths leading to the river, and also spreading of the water surface (particularly in rectilinear sections), ripples on the water surface, etc. Stretches of water (dark) and sandbanks (light) were clearly visible on sketches obtained from German aerial photographic surveying of the Oka River in the fall of 1941 (scale 1:200,000).

The nature of the river valley and bottom land must be established from maps, handbooks, reconnaissance, and surveying for the section which satisfies tactical requirements.

The river bed must be described from the standpoint of its relief and soil composition.

In planning crossings, the hydrologist should have daily observations of the water level for a number of years or at least the characteristic levels, i.e., maximum, minimum, average, and also data on the abruptness of rises and falls of the levels.

When a rise of level is expected, the relation between the depth at the crossing site and the indications of the nearest (highest) water-metering post should be established. To do this, a temporary water-metering post must be set up at the crossing.

If there are no permanent posts, a temporary water-metering post must be set up above the crossing. The two are connected by a telephone line to give flood warnings. The distance between the post and the crossing depends on the local conditions (speed of floods, etc).

A river valley with swampy sections or with steep shores is a difficult obstacle to surmount. The steepness and height of the shores make it difficult for artillery, tanks, and other transport to cross; a high steep shore is also an obstacle for the infantry.

The relief and vegetation of the bottom land also must be evaluated from the standpoint of its cover for troop movements to the river. If they do not provide cover, camouflaging is necessary.

Those changes which are brought about in the bottom land and the shore line by rise and fall of the level must also be taken into consideration.

1. Ferry Crossings

In ferry crossings, the most convenient section of a river is its bend. Approaches to the river should be covered if possible by vegetation. It is desirable to have a commanding position with respect to the enemy's bank on the flanks of the jump-off bank. The banks should not be steep or muddy and should permit descent without excessive losses. They should also be convenient for the assembly of ferries. The ferries should be assembled beforehand in the mouths of tributaries and in canals or secretly on the river bank so that they can by put into operation rapidly and suddenly.

The width of the river determines the composition of the first echelon of forcing troops. The influence of river width on speed of crossing is characterized by definite norms, which are cited in special instructions.

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A change in river level during crossing and a change in river width connected with it may make it necessary to lengthen bridges, use additional crossing equipment, etc.; therefore, a graphical dependency of river width on height of the level is set up for the crossing site selected.

Crossing should not be arranged on a narrow front or, especially, at one point. The intervals between crossings should range from 50 to 100 percent of the river width.

In the organization of ferry crossings, river depth at the landing must be at least 0.8-1 meter. Organized ferry or pontoon movements on rivers having shoals is impossible.

2. Fords

The following should be kept in mind when searching shallow places for fords: a ford is most probable on a definite section of the river bed, i.e., on sandbars. Sandbars are most frequently located in places where the river valley has broadened and, especially, where the river bed goes from one concave curve to another at an angle to the direction of the river valley without sticking to the main shores.

Craters from shells and bombs may make fords impassable. The enemy may deepen and mine the fords. When a ford is impassable from craters, the depth of the ford can be decreased by throwing bags of earth and stones and also heavy fagots into the craters.

When retreating behind a river or in defense of a river, fords are equipped with anti-infantry, antitank, and other obstacles. Posts, land mines, mines, and escarpments are used against tanks which do not navigate on rivers with depths over 1.5 meters. When constructing obstacles against amphibious tanks, the hydrologist must give the sappers reports on depth distribution in that section of the river.

3. Crossing by Swimming

Infantry, cavalry, and amphibious tanks make this type of crossing. Infantry and cavalry can cross when the water temperature is above 12 degrees centigrade.

Table 2. Width of a River Accessible for Crossing by Swimming (in meters)

	Speed of Current (m/sec)			
Type of Troops	Up to 0.5	0.5-1.0	1-1.5	Above 1.5
Infantry	120	70	50	30
Cavalry	350	300	200	150

Table 3. Crossing by Fording (depth of ford in meters)

Speed of Current (m/sec)	Infantry	Cavalry	Horse-Drawn Artillery and Trains	Tanks	Automobiles and Caterpillar Tractors
Up to 1.5	1.0	1.2	0.7	1.0	0.5
1.5-2	0.8	1.1	0.6	0.9	0.4
Over 2	0.6	1.0	0.5	0.8	0.3

4. Crossings over Ice

In making crossings over ice, reports must be obtained on the thickness of the ice and its strength. The latter depends on the origin of the ice and the temperature. The upper white layer of ice is usually weak. Crystallic ice is usually strongest and this layer is used in calculations to determine the passability of the ice, i.e., the thickness is taken without the sludge ice and the upper layer. The strength of ice decreases sharply in a thaw period. Table 4 gives the ice thickness required by various types of troops for crossing rivers up to 100 meters wide.

Table 4. Minimum Thickness of Ice for Crossings by Infantry and Cavalry

	Min Thickness of Ice for Various Mean Air Temp for 72 Hr		
Type of Troops	10° and Lower (cm)	5° (cm)	0° (cm)
Infantry in single file	4	5	6
" " double file	6	7	8
" " four columns	9	10	13
" " any order	15	17	21
Cavalry in single file	12	13	17

Special calculations of ice strength are made and special measures are taken to strengthen the ice when particularly heavy loads are expected on a crossing.

The ice cover may be strengthened by using boards to increase the passability of the ice. When the ice is thin, the passability can be increased by driving piles in the river bottom. Beams are installed on top of the piles, the pressure from which is transmitted to the piles as well as to the supports resting on the ice cover.

The ice can also be strengthened by freezing a layer of ice above the available ice cover. A bank is made of snow to help execute this task along the entire ice belt to be thickened. Water should be poured on in very thin layers. Of course, this measure is possible only when the temperature is considerably below freezing.

If thickness of the ice cannot be measured directly, it must be calculated from formulas.

The calculation must be made more accurate for the crossing site, with consideration for current speed, thickness of the snow cover on the ice, and the conditions of the fall freeze.

Experience gained in World War II in the construction of ice crossings is discussed in the works of G.R. Bregman, B.V. Proskuryakov, and N. N. Zubov, and in the instructions on the construction of ice crossings published by the Staff of the Engineering Corps of the Red Army in 1942.

Utilization of Water Routes for Operations of the River Fleet

In wartime, a river as a water route must be utilized by:

1. Navigation serving general state transportation.

2. Navigation serving military transport and transport of military supplies, troops, etc.

3. Military river fleets.

4. Naval vessels when being transferred through inland waterways.

The degree of participation of military river fleets and transport navigation in military operations is determined by: the hydrography of the country, the hydrographic regime of the water systems, and the possibility of building up a fleet on the given river system and transferring it both within the system and to systems close to it. In addition, the action of an enemy air fleet on the river fleet must be taken into consideration.

The following materials must be prepared in advance to provide for the efficient navigation of river vessels:

1. Detailed surveys showing an appendix of brief longitudinal profiles of those systems on which navigation is feasible and the indicated operations of river flotillas (scales 1:10,000, 1:25,000, 1:100,000). The bottom land must be described in horizontals (relief) up to the boundary of the higher levels.

2. Pilotage and pilots' charts

3. Hydrological outlines with a very detailed discussion of the characteristics that are important for navigation. These include:

a. Morphometric characteristics of the river and basin.

b. Depths, levels, and current speeds.

c. Width, radii of curvature.

d. Branching processes (list and characteristics of sandbanks, etc.).

e. Ice conditions.

f. Debacle and freezing.

g. Data about posts of the Hydrometeorological Service.

h. Meteorological characteristics (fogs, winds, etc.).

i. Meteorological data necessary for the organization of forecasts.

j. Methods of calculations and forecasts which are effective in the conditions of the given river.

k. Detailed characteristics of places for laying out coves and for wintering of ships (position, depth, protection from spring debacle, protection of coves, conditions of entry and exit of ships, etc.).

l. Reports on constructions in the river bed.

m. Reports on bridges, electrical transmission lines, etc.

For the most effective utilization of military river flotillas and for the best maneuvering under battle conditions, the command must be informed (with the available data for the entire area where the operations of military river flotillas are developing) of the state of the waterways, their width, depths, current speeds, and also of those changes which an expected change in the water content of a river may introduce.

Sandbanks are the main obstacles to navigation. To establish groups of standardized sandbanks, one must use handbook data or the data of direct soundings, if it is possible to make soundings or if information about them can be obtained.

The general picture of depths for a given time can be obtained by using a map with small sections, i.e., the difference between the water level indicated on the map and the level for the given day. It should be kept in mind that any drop of the level causes a drop of the mark for the ridge of the sandbank and vice versa.

In view of the variability of depth during navigation caused by variations in the water-bearing capacity of a river or a change in phase of its regime, command reports must be organized on depth and changes in depth must be forecast in time to allow for planning the operation.

Forecasting the depth of sandbanks requires: (1) forecast of the levels or discharges on the river and (2) relation between depth and discharges or levels. A relation between increments of levels and depth change gives the best results.

The least radius of curvature and the depth of the navigable zone must be determined from survey data taken of individual regions to characterize maneuverability conditions on the river.

The operating speed of ships should be determined in order to calculate the time required for their passage.

Maps should clearly designate the distribution of stretches of water and sandbanks on each section of the river and also the size and main characteristics of the river's hydrotechnical constructions (dams, sluices, bridges, etc.). The permissible above- and below-water dimensions of ships for passing the constructions should be indicated accurately.

All the characteristics listed above should also be considered from the standpoint of possible changes with level variations.

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The times of freezing and debacle of rivers determine the amount of time which ships can spend outside coves and the mobility of these ships. To plan the departure of ships from coves and river operations, the command must be supplied with reports on the times of spring debacles with forecasts of when the river will be clear of ice, etc.

Navigation during spring high water requires forecasts of levels and, particularly, maximum levels.

The hydrologist should have a collection of important dates for all years in which observations were made and should process them statistically to select the dates of the early, average, and late levels, the maximum, average, and minimum dates, the levels for the preceding years, and reports on these phenomena for the present year. Under conditions of military operations, however, the hydrologist himself may have to draw up both long and short-range forecasts. A description of methods used for drawing up hydrological forecasts is given in a number of works of the State Hydrographic Institute and in Military Hydrometeorological Forecasts, a work of the Central Forecasting Institute.

Observational data on the transparency of rivers are required in periods when submarines enter the mouths of large rivers, to clarify the problem of the submarines' visibility to enemy planes.

When setting up mine fields in a river, the following data is required:

1. Data on levels and depths and also forecasts of these elements for the proposed period of operation of the mine field to prevent possible "drying" of the mines, i.e., their appearance on the surface with a drop in level or their dropping to a great depth when the level rises.

2. Data on transparency to determine the probability of the mine field being detected by aerial reconnaissance; these data can be obtained by visibility measurements with a Sekki disk.

3. Data on the direction and magnitude of speeds at the place where the mine field is to be laid to calculate deviation of the mines from the vertical and their possible deepening by the force of the current.

When torpedoes are used in a shore defense system on a river, reports are required on currents (to calculate the drift of torpedoes) and on depth.

Water objects are camouflaged by a net (in which cut vegetation is interwoven) stretched over the object. The net is supported by floats.

In regions of populated points, rivers are camouflaged by false constructions of building roofs held afloat by colored matting stretched on wooden frames from rods and poles.

The water itself may serve as a camouflaging device; thus, when forcing water obstacles, troops sometimes use bridges with a flooded thoroughfare which are invisible from above [current press releases state that such bridges were used by the North Korean Army in the UN police action].

Use of Water Objects for Construction of Seaplane Bases

In view of the limited area of river waters, accurate data are required on the following in order to use the river for take-offs and landings of seaplanes: (1) distribution of straight sections in the river and their range, (2) depths of these sections, (3) direction and magnitude of surface currents, (4) wave heights for various wind speeds and directions, (5) presence of hydrotechnical constructions, especially high-voltage transmission lines crossing the river on the sections.

If possible, one should have a bathymetric map of a lake if it is to be used as a seaplane base. The run lines (if only for the eight main quarters) should be established on the map for the individual sections and directions. If currents with speeds over 0.25-0.50 meter per second are observed, they should be measured and indicated on the map. Data on wave heights for various wind speeds and directions should be indicated; if wave heights cannot be measured directly, they should be determined from formulas. The soil type of shore and shore zone should be indicated on the map.

In order to establish the times when rivers and lakes can be used as seaplane bases, reports and forecasts must be compiled on their freezing and debacle. These forecasts and calculations require the following meteorological data: wind types in the lake region, air and water temperatures, and precipitation in the lake basin.

<u>Certain Morphometric Characteristics of Rivers Which Are Necessary for Hydrological Descriptions</u>

In drawing up hydrological descriptions of rivers in wartime, it is necessary to establish the relations between certain morphometric characteristics of basins and to make a regional division of the parameters determining these relations. Below is an example of establishing these relations, which play an important role not only in hydrological descriptions but also in hydrological calculations, in particular in drawing up preliminary plans for utilizing previously unstudied rivers of small basins for power purposes.

1. Relation between River Length (L) and Basin Area (F)

More than 295 basins, with areas from 450 to 5,000 square kilometers in central USSR were studied in order to establish this relation. The relation is approximately defined by the equation $L = aF^{0.6}$, where the parameter <u>a</u> varies from 1.5 to 4.3; the average value of <u>a</u> is 2.9.

For the Ukraine, A. V. Ogiyevskiy obtained $L = aF^{0.5}$. In this case, <u>a</u> varies from 1.5 to 2.5, with an average value of 2.0. To construct this dependency, the areas of the basins were measured by a planimeter from three- and ten-verst maps. The length of rivers was measured with a micrometric gage.

Analysis of the graph of the function $L = f(F)$ (Figure 1) established that the points are scattered for a number of reasons, among which the following should be mentioned:

a. If a river has a large tributary in its upper reaches, we are actually taking as its source something which has a title equal to it, which is hydrographically incorrect. Zupan recommends that the length in the upper reaches be taken with respect to the larger tributary.

b. For the same river areas, the length may vary because of the number and sharpness of curves.

c. The form of the river basin and the position of the river in the plan plays an important role; basins of small rivers are quite diverse.

2. Classification of Longitudinal Profiles of Small Rivers (Problem of Drop)

In view of the insufficient data on longitudinal profiles of small basins, their classification by generalizing data on available profiles of small rivers is of great practical interest. As an example, we cite the generalizations made in relative coordinates for the central part of European USSR (Figure 2). In this generalization, the entire length of the river and the entire drop from source to mouth was taken as 100 percent.

From the data of 22 profiles, two extreme types of rivers were classified: Type I, rivers in which the drop is distributed fairly uniformly along the length of the river; Type II, rivers in which a considerable drop is concentrated in the upper part. Type II is observed on the northeast slopes of the Central Russian elevation, while the first is observed on the opposite slopes.

For approximate characteristics of the drop of rivers, we cite data for various rivers in Table 5 below:

Table 5. Drop of Rivers per Kilometer (in centimeters)

	Lowland Rivers	Foothill Rivers	Mountain Rivers
Very large rivers	4-12	--	--
Large rivers	6-15	15-30	--
Average rivers	10-30	25-100	100-300
Small rivers	20-100	50-200	200-500

3. Relation between Discharge Elements of Rivers and Elements of the Bed

The aberage perennial (average spring level) hydraulic discharge modulus must be closely related to the representative (average spring level) cross section. Thus, knowing the average perennial discharge of a given river and having determined by analysis the monthly distribution, one can determine the amount of the average perennial (average spring level) discharge and the (average spring level) hydraulic modulus with the help of the (average spring level) deviation of the given section. Further, the graphical relationship of this quantity with areas of the representative cross sections for rivers in the given region should be established.

This relationship can be used to determine the approximate representative dimensions of a bed without soundings, which may be of interest under war conditions. A similar relationship can be obtained for the characteristics of the average cross section of the representative spring high water. The relationship between cross section and river depth (or width) is determined from the assumption that the river bed is usually of parabolic form.

Use of Ice for Construction of Defense Installations

The extensive winter operations of the Red Army forced attention on the use of ice for construction of fortifications. Snow can serve as a defense against rifle and machine-gun fire only if it is well-packed. Even under these conditions, however, a cover which cannot be pierced (by non-armor-piercing bullets) is very thick, reaching 3.5 meters. Ice, which can be obtained by layer-by-layer freezing of water or snow sprayed with water, offers slightly more resistance to piercing. In addition, the cover can be made by breaking blocks off the ice cover of rivers, lakes, and swamps and putting them together on damp snow. An ice cover about 2 meters thick offers protection from non-armor-piercing bullets. Frozen ground gives higher resistance to penetration; sandy-gravelly soil (70 centimeters required for protection from non-armor-piercing bullets) is the best, followed by sandy frozen ground (80 centimeters) and clayey soil and clay (90 centimeters).

Of the simpler materials used in winter, those having the highest strength and resistance to piercing are ice solution (packed and frozen mixture of sand and water -- water 15-20 percent of the volume of sand) and ice concrete (packed and frozen mixture of sand, gravel, or rubble, and water).

In enclosed fortifications, ice concrete should be protected from thawing from below by a layer of soil, straw, or boards, etc.

Ice solution and ice concrete are more than four times stronger than ordinary ice. An ice solution 30-40 centimeters thick is not pierced by bullets, nor is ice concrete (with rubble) 20-25 centimeters thick.

The resistance of ice solution and ice concrete to penetration by shells is characterized by the following comparative data: penetration into an ice solution corresponds approximately to penetration into dense sand; penetration into ice concrete corresponds approximately to penetration into cobblestone masonry.

Ice concrete (or the slightly poorer ice solution) is used in the following cases: (1) for solid interlayers in reinforced earthen-wooden fortifications, and (2) as antibullet or antifragment constructions with the thickness indicated above.

Although it has considerably less strength than cement, ice concrete has several points of merit: it does not require expenditure of cement, solidifies rapidly in winter, and is easily repaired by closing shell holes with ice solution or ice concrete.

Calculation of the Change of Soil Moisture

It is important to know the state of moisture in soils in forecasting the passability of a territory, in determining the runoff coefficient, in establishing the times to water farm crops, etc. We point out that a graph (see Figure 3) drawn up by the author on the basis of an investigation of soil moisture can be used approximately to calculate the time required for soil moisture to change in dependence on various moisture states, mean diurnal temperatures, and certain average soil conditions. If a forecast of precipitation and temperatures has been given and the soil moisture is known at the moment, it is easy to obtain an approximate idea of what the moisture state of the soil will be after the precipitation and temperature conditions forecast actually occur. The number of days the soil will remain in a certain moisture state can also be predicted.

Conclusions

The hydrological problems connected with hydrometeorological service to troop operations are not limited to the problems discussed in this work; they are much broader. Contemporary hydrology is in a position to solve a number of new problems.

Despite the fact that many problems in military hydrology were properly developed only during the war, hydrology rendered considerable aid to the front. Reconnaissance of water barriers and the compilation of military-hydrological studies of a locality developed rapidly. Also, considerable work has been done in the drawing up of plans for flooding water barriers by spring high water and also in hydrological calculations for the construction of water obstacles and other forms of engineering fortifications.

The most pressing tasks now are:

1. Checking the values of a number of generalized parameters in the form of isolines. This will make possible the study of hydrological phenomena on small rivers, which, in view of their great number, are of the greatest interest to the command.

2. Devising a number of hydrographic laws for the elements of the bed, the bottom land, and the valley to aid the compilation of hydrological descriptions of water objects.

The accuracy of any engineering calculations is no better than the accuracy of observations. This obvious principle applies to hydrological calculations and, in particular, to methods of graphing "safety curves," for which the recently observed tendency to complicate calculations (for example, by consideration of an excess which in no way corresponds to the initial data) is completely without scientific basis. The graphical method of distribution curves, which is sometimes used in hydrology without special scientific basis, can nevertheless be of great help in solving the most complex problems. As an example, we cite M. A. Velikanov's determination of catastrophic maximum discharge by adding the probabilities of occurrence of the separate hydrological elements or, at least, the elements which can be measured producing this effect.

[Figures follow.]

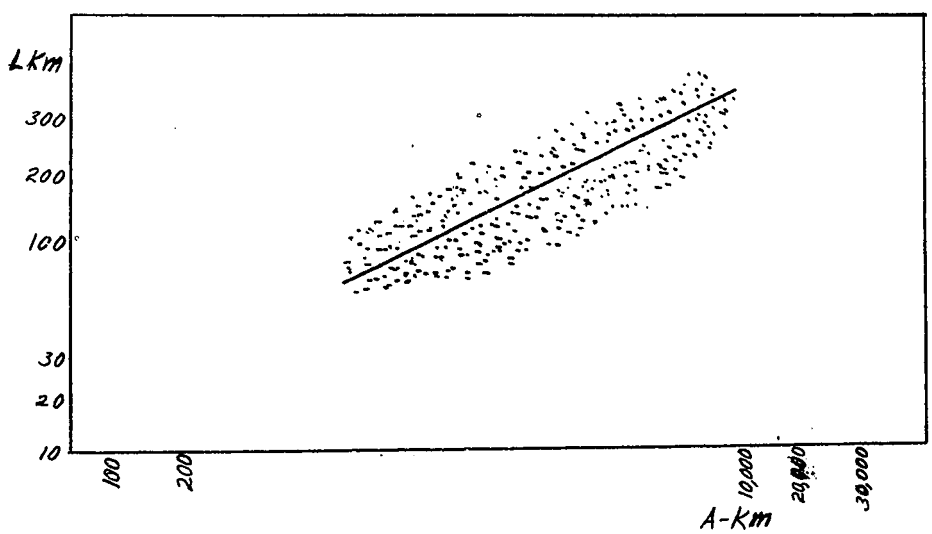

Figure 1. An Example of Finding the Approximate Dependency Between River Length and Basin Areas for the Central Part of European USSR

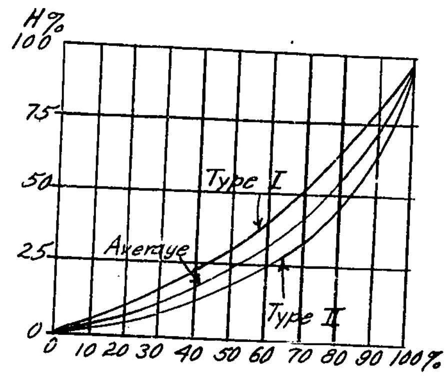

Figure 2. An Example of "Typization" of the Longitudinal Profiles of Rivers of Small Basins for the Central Part of European USSR

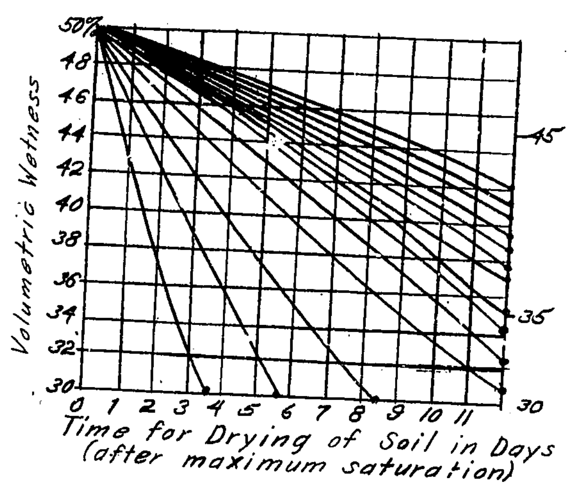

Figure 3. Graph for Determining Approximate Time of Drying up of Soils

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